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Variation of *Schoenoplectus gemmifer* in Morphological Comparison with *S. mucronatus* and *S. triangulatus*

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Schoenoplectus gemmifer was characterized as a new species in having the pistil with two stigmas, linear leaf blade and gemmate habit. However, individuals of the species growing in still water are sometimes confused with *S. mucronatus* var. *mucronatus* or *S. triangulatus*. In a morphological comparison by the principal component analysis, still water-form of *S. gemmifer* was separated roughly from the two species by three characters; the number of stigmas, shape of a transverse section of the nutlet and number of perianth segments per nutlet. The distinctions are provided in a key to the species.

Key words: Cyperaceae, morphological comparison, principal component analysis, *Schoenoplectus gemmifer*.

Schoenoplectus (Rchb.) Palla is one of the segregated genera from *Scirpus* L. s. l., Cyperaceae (Palla 1888a, 1888b, Goetghebeur 1998). Thirty-four species and three hybrids are known in the genus of the East Asia and North American regions (Hayasaka and Ohashi 2000a, Smith and Hayasaka 2001).

Sato and Imae (1990) found an unknown plant of *Schoenoplectus* in Aso of Kyushu, and reported it as "Hatabe-Kangarei" as the Japanese name. This plant differed from *S. mucronatus* var. *mucronatus* and *S. triangulatus* in having two instead of three stigmas, but resembled them in the tufted, triquetrous culms and triquetrous involucral bracts. The plant was intermediate between the two species in the morphological characters, such as the width of culms, length and width of spikelets, length of anthers, wrinkled surface of nutlets and relative length of perianth segment to nutlet. However, morphological analyses were not performed in detail. Sato et al. (2003) recognized this plant as a new species, *S. gemmifer*, based on the two stigmas, linear leaf blade and gemma. The latter two characters tend to develop on individuals growing in rills and streams but do not appear frequently in still water. Thus, individuals of *S. gemmifer* without linear leaf blades and gemma were confused with those of *S. mucronatus* var. *mucronatus* and *S. triangulatus*.

In order to confirm that *S. gemmifer* differs from the other species in morphological characteristics in addition to the linear leaf blade and gemma, we compared 21 characters by means of principal component and other statistical analyses.

Materials and Methods

Three plants of the genus *Schoenoplectus* (Cyperaceae), *S. gemmifer* C.Sato, T.Maeda

Table 1. Localities and numbers of material plants of *Schoenoplectus gemmifer* (GEM), *S. mucronatus* var. *mucronatus* (MUC) and *S. triangulatus* (TRI) for morphological analyses

Species	Locality code	Locality	No. of plants		
			Wild	Cultivated	Total
GEM	Zz	Zizobaru, Kusu, Oita Pref.	4	2	6
	Ng	Nagare, Aso, Kumamoto Pref.	14	3	17
	Sm	Senomoto, Aso, Kumamoto Pref.	19	2	21
	Hb	Hatabe, Aso, Kumamoto Pref.	4	3	7
	total		41	10	51
MUC	Hm	Hitotsume, Yamaga, Kumamoto Pref.	16	3	19
	Sd	Mt. Syodai-san, Tamana, Kumamoto Pref.	12	2	14
	St	Mt. Shira-take, Amakusa, Kumamoto Pref.	8	2	10
	total		36	7	43
TRI	Kk	Kamikobata, Makabe, Ibaragi Pref.	1		1
	Sa	Shimoaruji, Fukuyama, Hiroshima Pref.	2	1	3
	Tk	Takumi, Kusu, Oita Pref.	7		7
	Td	Mt. Tatsuda-yama, Kumamoto, Kumamoto Pref.	5	4	9
	Mb	Matsuba, Kuma, Kumamoto Pref.	9	4	13
	It	Ishitobi, Minamata, Kumamoto Pref.	9	4	13
	total		33	13	46
Grand Total			110	30	140

& Uchino, *S. mucronatus* (L.) Palla var. *mucronatus* and *S. triangulatus* (Roxb.) Soják, were used for the morphological measurements. *S. mucronatus* has three varieties with triquetrous culms (Kohno et al. 2001). The typical variety, var. *mucronatus*, is different from var. *tataranus* and var. *ishizawae* in having unwinged culms. Plants were collected from the western part of Japan (Table 1 and Fig. 1). Some of their individuals were cultivated for more than one year in the experimental garden at the Faculty of Science, Kumamoto University. Each individual was cultivated in a pot in still water, the depth of which was the same as the height (ca. 15 cm) of the pot. For morphological measurements, culms with matured spikelets were collected from individuals.

Nineteen characters measured are as follows (Fig. 2); length of culm (LCU), width of culm (WCU), length of involucral bract (LIB), number of spikelets per culm (NSP), length of spikelet (LSP), width of spikelet (WSP), number of glumes per spikelet (NGL), length of glume (LGL), width of glume (WGL), length of pistil (LPI), number of stigmas (NST), length of anther (LAN), number of nutlets per spikelet (NNU), length of nutlet (LNU), width of nutlet (WNU), height of outside (HON) and axis side (HAN) in biconvex nutlet, number of perianth segments per nutlet (NPS), length of perianth segment (LPS). In addition, two statistical characters, the ratis of HAN to HON (AN/ON) and the relative length of perianth segment to nutlet (PS/NU), were calculated in nutlets for which we could measure all values of HON, HAN, LNU and LPS.

The principal component analysis was made on the modes of the characters NST and NPS and the mean values of the other 19 characters. The package program published by Kyoritsu Shuppan Co. Ltd. (1984) was

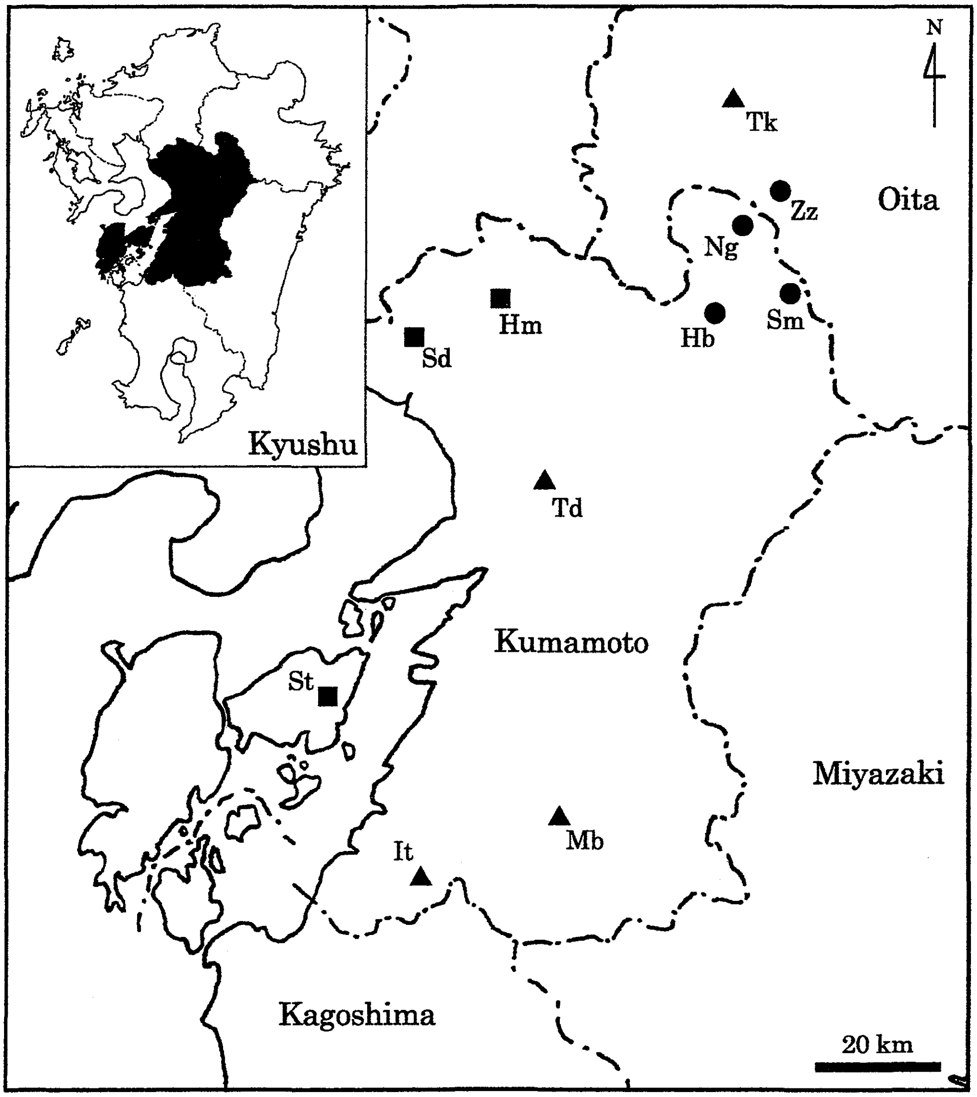

Fig. 1. Localities of material plants of *Schoenoplectus gemmifer* (●), *S. mucronatus* var. *mucronatus* (■) and *S. triangulatus* (▲) in Kyushu, Japan. The alphabetical codes correspond to the locality codes in Table 1.

used for the analysis.

Results

The numerical data of the 19 characters, except for NST and NPS, are shown in Table 2 for *S. gemmifer*, *S. mucronatus* and *S. triangulatus*. The comparisons of the characters NST and NPS were carried out with reference to the modes because they were discretely variable and their ranges were narrow.

In wild collected specimens, the numerical ranges of the 19 characters of *S. gemmifer* overlapped with those of both the other species (Table 2). The three characters of LIB, NSP and LSP were not significantly different ($p > 0.05$) between *S. gemmifer* and *S. mucronatus*, but *S. triangulatus* was larger

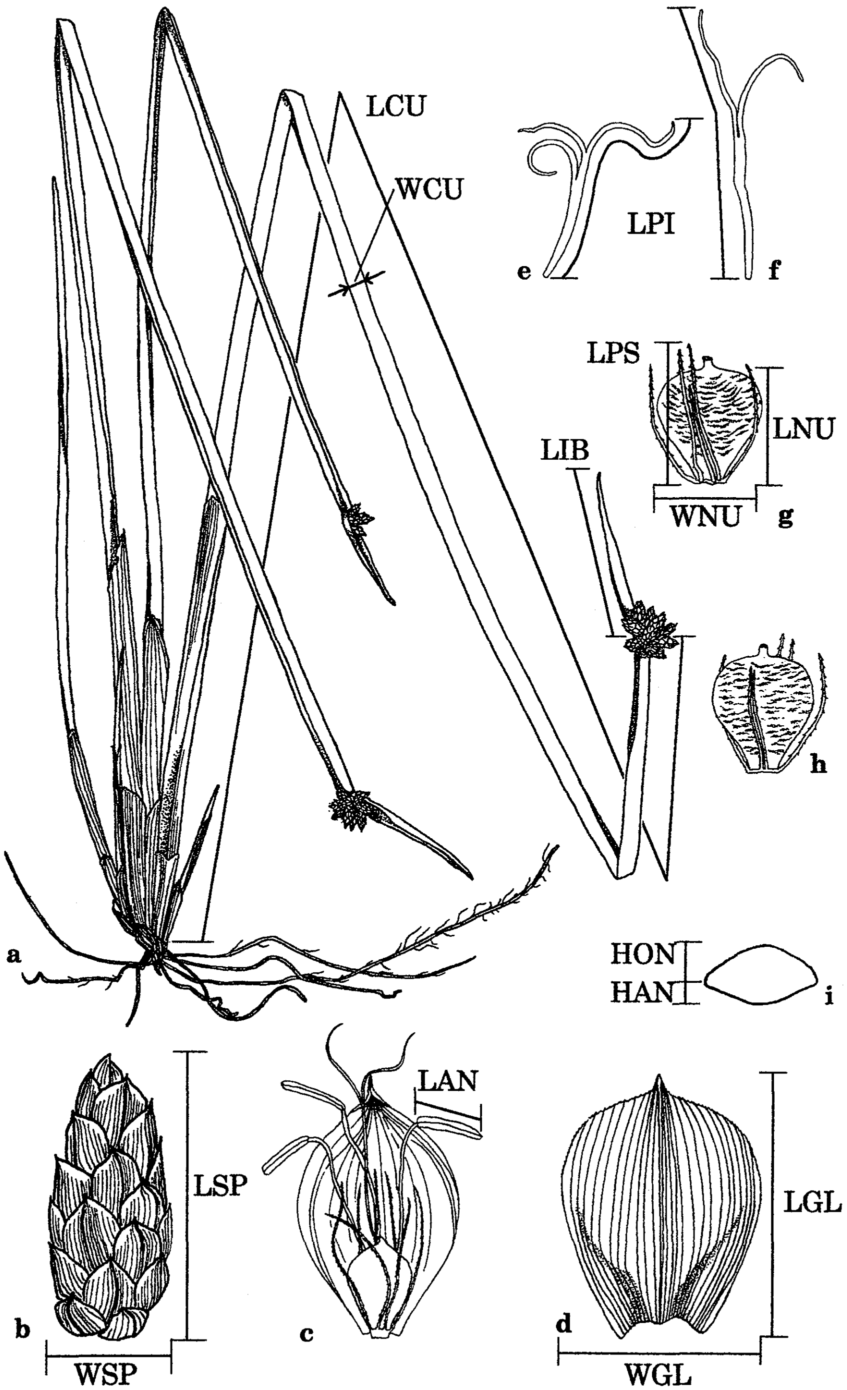

Fig. 2. Parts of *Schoenoplectus* plants measured, except for the countable characters such as the number of spikelets per culm. a: whole plant. b: spikelet. c: flower with a glume. d: glume. e and f: pistil with three (e) and two (f) stigmas. g–i: nutlet with seven perianth segments at the view from the out side (g), axis side (h) and transverse section (i). LCU: length of culm. WCU: width of culm. LIB: length of involucral bract. LSP: length of spikelet. WSP: width of spikelet. LAN: length of anther. LGL: length of glume. WGL: width of glume. LPI: length of pistil. LNU: length of nutlet. WNU: width of nutlet. LPS: length of perianth segment. HON: height of outside in biconvex nutlet. HAN: height of axis side in biconvex nutlet.

Table 2. Numerical data for 19 morphological characters of *Schoenoplectus gemmifer* (GEM, n = 51), *S. mucronatus* var. *mucronatus* (MUC, n = 43) and *S. triangulatus* (TRI, n = 46)

Character	Species	Wild condition				Cultivated condition			
		N	Mean	S.D.	Range	N	Mean	S.D.	Range
LIB (cm)	GEM	123	3.99	0.94	1.8–7.0 ┐	30	4.53	1.08	2.4–7.0
	MUC	101	4.36	2.27	1.0–9.7 ┘	20	6.85	1.26	4.2–8.3
	TRI	97	7.54	1.93	3.3–11.5	37	8.09	1.73	5.0–11.8
NSP	GEM	123	6.41	1.51	3–11 ┐	30	4.83	1.26	3–8 ┐
	MUC	102	5.89	2.67	1–13 ┘	20	6.25	1.45	4–9 ┘
	TRI	98	12.47	3.43	6–22	37	11.27	2.88	8–17
LSP (mm)	GEM	366	10.84	1.74	5.2–15.1 ┐	90	11.51	1.87	8.4–15.9 ┐
	MUC	265	10.47	1.39	6.7–15.2 ┘	60	10.69	1.28	7.8–13.5 ┘
	TRI	294	18.22	5.86	8.1–33.9	111	18.35	3.37	12.2–25.5
WSP (mm)	GEM	366	5.08	0.55	3.6–7.1 ┐	90	5.17	0.72	3.9–7.4
	MUC	265	4.74	0.49	3.1–7.8 │	60	4.68	0.37	3.8–5.6 ┐
	TRI	294	4.97	0.87	3.1–8.7 ┘	111	4.72	0.56	3.6–6.5 ┘
LNU (mm)	GEM	1845	2.08	0.15	1.7–2.6	450	1.92	0.16	1.6–2.3
	MUC	1304	2.02	0.12	1.7–2.5 ┐	299	2.03	0.17	1.7–2.4
	TRI	1465	2.02	0.15	1.6–2.5 ┘	555	1.96	0.13	1.6–2.3
HAN (mm)	GEM	1826	0.38	0.07	0.2–0.6	450	0.37	0.07	0.2–0.5
	MUC	1303	0.26	0.06	0.1–0.4	299	0.24	0.06	0.1–0.4
	TRI	1440	0.24	0.07	0.1–0.5	555	0.21	0.06	0.1–0.4
WNU (mm)	GEM	1845	1.71	0.11	1.2–2.1	450	1.63	0.15	1.3–2.0
	MUC	1304	1.78	0.13	1.0–2.4	299	1.78	0.17	1.4–2.2
	TRI	1465	1.64	0.13	1.0–2.1	555	1.48	0.10	1.3–1.8
LAN (mm)	GEM	1683	1.39	0.20	0.8–1.9	450	1.46	0.10	1.2–1.7
	MUC	1145	1.27	0.11	0.9–1.7	300	1.21	0.11	1.0–1.5
	TRI	1406	2.45	0.31	1.7–3.8	533	2.39	0.26	1.7–3.1
LPI (mm)	GEM	1559	3.34	0.59	1.6–6.1	450	2.87	0.38	1.4–5.0
	MUC	808	2.86	0.33	1.5–3.9	300	2.47	0.37	1.4–3.6
	TRI	890	4.77	0.79	2.4–8.0	555	4.65	0.68	2.3–6.2
LGL (mm)	GEM	1845	4.13	0.29	3.0–5.6	450	4.01	0.24	3.2–4.7
	MUC	1309	3.12	0.24	2.2–3.8	300	3.15	0.17	2.7–3.7
	TRI	1459	4.89	0.42	3.5–6.0	555	5.01	0.41	4.0–6.0
LPS (mm)	GEM	1842	2.44	0.17	1.8–3.0	450	2.30	0.14	1.8–2.8
	MUC	1304	1.97	0.14	1.5–2.8	299	1.96	0.20	1.5–2.5
	TRI	1453	2.86	0.34	1.5–3.9	555	2.83	0.33	2.1–3.6
PS/NU	GEM	1842	1.18	0.09	0.78–1.61	450	1.12	0.11	0.91–1.56
	MUC	1304	0.98	0.06	0.75–1.40	299	0.96	0.05	0.83–1.10
	TRI	1453	1.42	0.17	0.88–1.94	555	1.45	0.18	0.96–1.88
WCU (mm)	GEM	123	5.84	1.28	3.2–9.7	30	3.96	0.56	2.6–5.0
	MUC	101	3.44	0.64	2.1–4.9	20	3.37	0.34	2.6–3.9
	TRI	98	7.69	1.81	4.2–11.7	37	6.07	1.07	3.9–8.3
WGL (mm)	GEM	1845	2.46	0.27	1.5–3.6	450	2.53	0.24	1.9–3.2
	MUC	1309	2.75	0.21	1.9–3.3	300	2.79	0.16	2.3–3.2
	TRI	1459	2.66	0.31	1.6–3.7	555	2.58	0.27	1.8–3.3
LCU (cm)	GEM	123	64.45	12.69	38.5–101.1	30	49.52	4.47	40.3–57.0
	MUC	101	85.34	26.92	42.0–145.5	20	66.68	8.86	53.0–89.3
	TRI	98	112.14	22.03	71.4–171.8	37	93.97	15.49	64.7–121.3
NGL	GEM	364	28.40	6.69	10–46	90	40.30	8.84	26–59
	MUC	265	33.33	7.74	12–50	60	31.82	6.22	20–46
	TRI	293	62.09	25.25	19–122	111	64.86	16.92	35–103
NNU	GEM	364	19.89	6.65	5–38	90	20.93	7.08	8–42 ┐
	MUC	265	25.41	8.08	0–42	60	18.98	6.99	4–35 ┘
	TRI	293	40.88	24.51	4–97	111	38.59	14.82	12–79
HON (mm)	GEM	1826	0.53	0.08	0.3–0.8	450	0.50	0.07	0.3–0.7
	MUC	1303	0.71	0.10	0.4–1.0	299	0.75	0.09	0.5–1.0
	TRI	1440	0.59	0.10	0.3–0.9	555	0.59	0.08	0.4–0.8
AN/ON	GEM	1826	0.74	0.19	0.25–1.50	450	0.75	0.18	0.33–1.33
	MUC	1303	0.37	0.11	0.10–0.80	299	0.34	0.11	0.10–0.67
	TRI	1440	0.42	0.16	0.11–1.25	555	0.37	0.13	0.14–1.00

LIB: length of involucral bract. NSP: number of spikelets per culm. LSP: length of spikelet. WSP: width of spikelet. LNU: length of nutlet. HAN: height of axis side in biconvex nutlet. WNU: width of nutlet. LAN: length of anther. LPI: length of pistil. LGL: length of glume. LPS: length of perianth segment. PS/NU: relative length of perianth segment to nutlet. WCU: width of culm. WGL: width of glume. LCU: length of culm. NGL: number of glumes per spikelet. NNU: number of nutlets per spikelet. HON: height of outside in biconvex nutlet. AN/ON: rate of HAN to HON. There are no significant differences ($P > 0.05$) between species sharing the bracket.

than the others in the values of these characters. The character WSP was not significant between *S. gemmifer* and *S. triangulatus*. There was no significant difference in the character LNU between *S. mucronatus* and *S. triangulatus*, but the mean value of *S. gemmifer* was larger than those of the other two species. There were significant differences in the other 14 characters among the three species in spite of the overlap of the numerical ranges. *Schoenoplectus mucronatus* tended to be smaller than *S. triangulatus* in the mean values in almost all cases. In the value of the character HAN, however, *S. gemmifer* was larger than the other two species, and *S. mucronatus* was larger than *S. triangulatus*. In seven characters, WNU, LAN, LPI, LGL, LPS, PS/NU and WCU, *S. gemmifer* was intermediate in mean value between the other two species. *S. gemmifer* was smaller in five characters, WGL, LCU, NGL, NNU and HON, than the other two species. In addition, *S. mucronatus* was larger than *S. triangulatus* in the character WGL. *S. gemmifer* had a larger mean value of AN/ON than those of the other two species due to the larger HAN and smaller HON.

In the cultivated specimens, there were no significant differences between *S. gemmifer* and *S. mucronatus* in three characters, NSP, LSP and NNU (Table 2). In the character WSP there was no significant difference between *S. mucronatus* and *S. triangulatus*. There were significant differences in the other 15 characters among the three species in spite of the overlap of the numerical ranges. *S. gemmifer* was larger in the mean value of character HAN than the other two species. This was the same result as in the wild condition. In eight characters, WNU, LAN, LPI, LGL, LPS, PS/NU, WCU and NGL, *S. gemmifer* was intermediate in mean value between *S. mucronatus* and *S. triangulatus*. The character NGL was different from the case in the wild condition. In five characters, LIB, LNU, WGL, LCU and HON, *S. gemmifer* was smaller than the other two species. The two characters LIB and LNU were different from the case of the wild condition. *S. gemmifer* was larger in the mean value of AN/ON than the other two species and this was the same as in the wild condition.

The statistical character AN/ON affects the shape of a transverse section of the nutlet. *Schoenoplectus gemmifer* indicated higher values of AN/ON than *S. mucronatus* and *S. triangulatus* (Table 2). Thus, the former tended to have biconvex nutlets and the latter two tended to have compressed trigonous ones (Fig. 3, a–c). The statistical value of PS/NU of *S. gemmifer* was intermediate between those of the other two species (Table 2 and Fig. 3, d–f). In addition, *S. gemmifer* was also intermediate between the other two species in the degree of wrinkling on the surface of the nutlets, a qualitative character (Fig. 3, g–h). The nutlets of *S. mucronatus* had transversely wrinkled surfaces, but those of *S. triangulatus* had inconspicuously wrinkled ones.

The number of stigmas (NST) varied from one to four among pistils. Pistils were able to be classified into eight types by the number and length of the stigmas, that is, one type (M) in pistils with one-stigma, two types (D_1 and D_2) in two-stigmas, four types (T_1 to T_4) in three-stigmas and one type (Te) in four-stigmas (Fig. 4). The inflorescence of *Schoenoplectus* is composed of several spikelets having many flowers which differed in the NST and pistil type from flower to flower. Nevertheless, the primary mode of *S. gemmifer* was type D_1 (84.8 %) having two stigmas of similar length despite the occurrence of seven stigmatic types. Only the four-stigma type, Te, (Table 3) was absent. In the cultivated condition, only three pistil types of *S. gemmifer* were observed and type D_1 (92.7 %) was also most prevalent. In contrast, *S. mucronatus* and *S. triangulatus* were

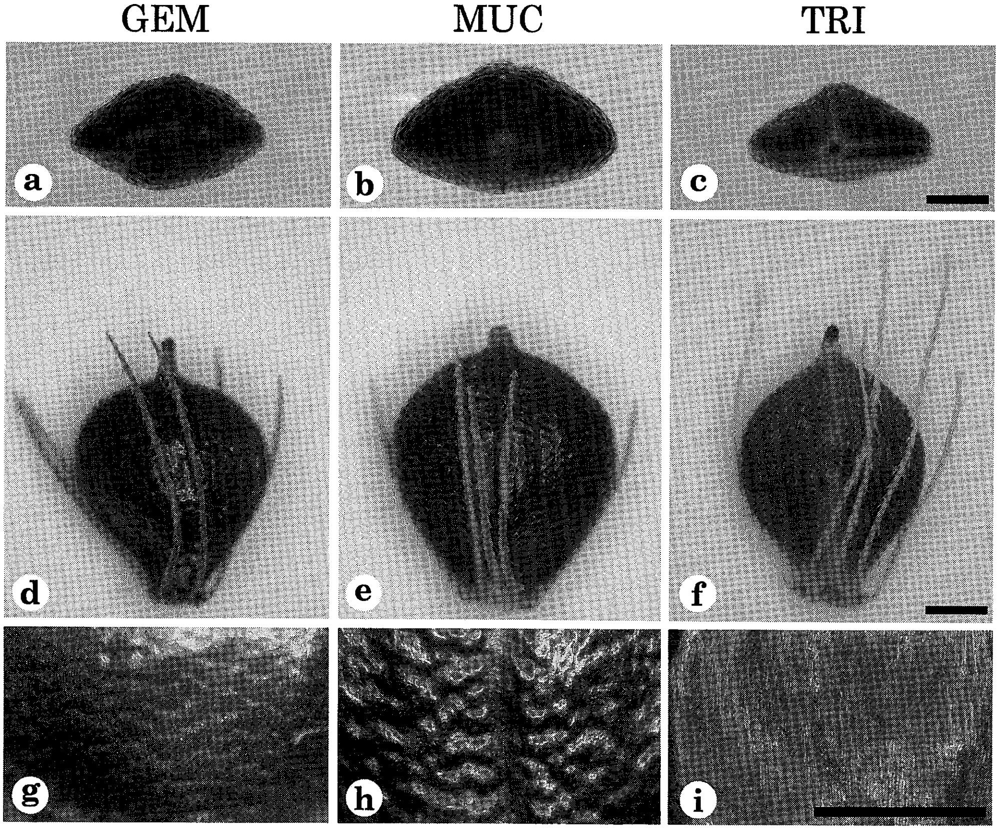

Fig. 3. Nutlets and perianth segments of *Schoenoplectus gemmifer* (GEM) and *S. mucronatus* var. *mucronatus* (MUC) and *S. triangulatus* (TRI). Shape of the transverse section of the nutlet (a–c), comparison of the perianth segments of the nutlet (d–f) and wrinkles of the nutlet surface (g–i). Bars indicate 0.5 mm.

predominatly type T_1 (98.3 % and 85.4 %, respectively) in which the three stigmas were of similar length. Types M and D_2 were not found and type D_1 was found exceptionally in a few flowers of *S. triangulatus* from the Td population. This was true under both wild (0.8 %) and cultivated (1.1 %) conditions. Thus, *S. gemmifer* tended to have type D_1 pistils with two-stigmas but the other two species had type T_1 with three-stigmas.

The results of measurement of NPS are shown in Table 4. The nutlets of *S. gemmifer* had six (46.9 %) or seven (45.5 %) perianth segments with high frequency in the wild condition. The modes of the populations Ng and Hb were six but those of the populations Zz and Sm tended towards seven. However, in the cultivated condition, the modes of all four populations were seven perianth segments (76.0 %). The modes of *S. mucronatus* were six perianth segments (95.6 % in the wild condition and 98.3 % in the cultivated condition) and the frequencies of seven and five perianth segments were small. In *S. triangulatus*, the mode was six perianth segments although the Sa population had a mode of five. Thus, the modes were six or seven perianth segments in *S. gemmifer*, six in *S. mucronatus* and six with a low frequency of five in *S. triangulatus*. Seven

Table 3. Number of pistils with different numbers of stigmas (NST) and pistil types of *Schoenoplectus gemmifer* (GEM), *S. mucronatus* var. *mucronatus* (MUC) and *S. triangulatus* (TRI) in the wild and cultivated conditions

Species	Locality NST	1	2		3				4	Total
	Pistil type	M	D_1	D_2	T_1	T_2	T_3	T_4	Te	
GEM	Wild									
	Zz		67	1	26	11	16	4		125
	Ng	1	318	43	48	9	21	9		449
	Sm		812	11	3	3	4	2		835
	Hb	1	134		11	3	10	1		160
	Total	2	1331	55	88	26	51	16		1569
	(%)	(0.1)	(84.8)	(3.5)	(5.6)	(1.7)	(3.3)	(1.0)		(100.0)
	Cultivated									
	Zz		78		5		7			90
	Ng		117		17		1			135
	Sm		89		1					90
	Hb		133		1		1			135
	Total		417		24		9			450
	(%)		(92.7)		(5.3)		(2.0)			(100.0)
MUC	Wild									
	Hm				501	5	1		3	507
	Sd				177	1				178
	St				116	2	1		1	119
	Total				794	8	2		4	808
	(%)				(98.3)	(1.0)	(0.2)		(0.5)	(100.0)
	Cultivated									
	Hm				135					135
	Sd				74				1	74
	St				90					90
	Total				299				1	300
	(%)				(99.7)				(0.3)	(100.0)
TRI	Wild									
	Kk				15					15
	Sa				67				1	67
	Tk				286	16	9	4		315
	Td		7		130	67	14	1	1	219
	Mb				129	3	3			135
	It				131	3	1			135
	Total		7		758	89	27	5	2	888
	(%)		(0.8)		(85.4)	(10.0)	(3.0)	(0.6)	(0.2)	(100.0)
	Cultivated									
	Tk				45					45
	Td		3		147					150
	Mb				179		1			180
	It		3		177					180
	Total		6		548		1			555
	(%)		(1.1)		(98.7)		(0.2)			(100.0)

The locality codes correspond to those in Table 1 and the pistil types correspond to those in Fig. 4.

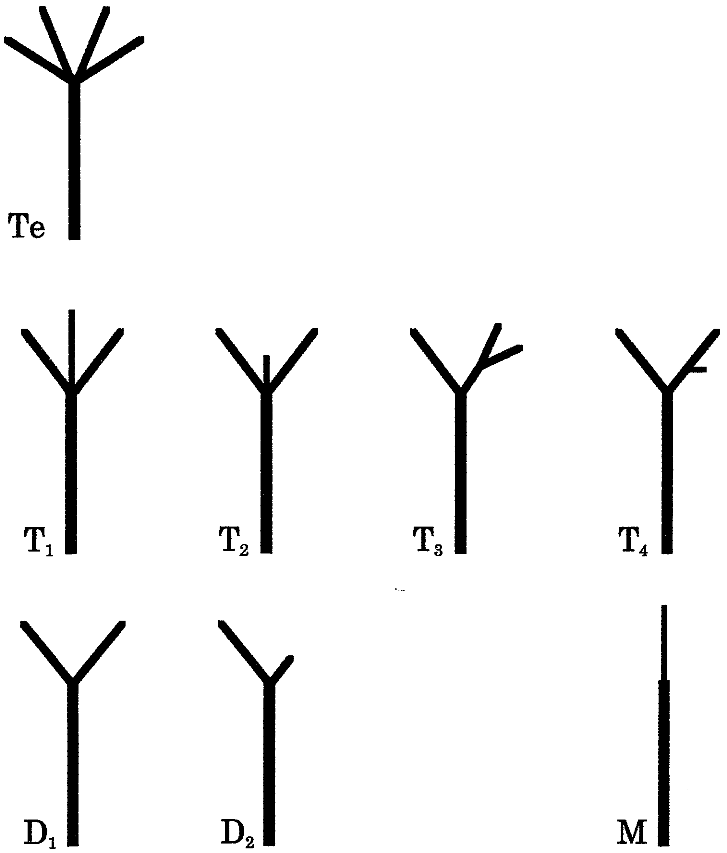

Fig. 4. Schematic diagrams of the pistil types of *Schoenoplectus*. Each type was based on the number and length of the stigmas. Te: 4 stigmas. T_1, T_2, T_3, T_4: 3 stigmas. D_1, D_2: 2 stigmas. M: 1 stigma.

perianth segments were exceptional in *S. gemmifer*.

Principal component analysis was carried out on the morphological data. The cumulative variance of the first three principal components (PC1 to PC3) and the loadings of 21 characters are shown in Table 5. These components contained 75.0 % of the total variance. The first principal component (PC1) accounted for 41.9 % of the total variation. This component was regarded as a size factor because the first component loading showed high positive loadings on characters expressing plant size, such as the characters LAN, LSP, NSP, NGL, LGL, LPS, PS/NU, LPI, WCU, NNU, LIB and LCU. The character loading most heavily was the LAN. A higher score in this component tended to indicate a large plant body. The second principal component (PC2) accounted for 22.7 % of the total variance and the second component loadings had high loadings on the five characters AN/ON, HON, NST, HAN and NPS. This component was regarded as an nutlet factor because four of the five characters having high loadings were concerned with the shape of the nutlets, such as the characters AN/ON, HON, HAN and NPS. The remaining character, NST, had high negative loading. Higher scores in the com-

Table 4. Number of nutlets with different numbers of perianth segments (NPS) of *Schoenoplectus gemmifer* (GEM), *S. mucronatus* var. *mucronatus* (MUC) and *S. triangulatus* (TRI) in the wild and cultivated conditions

Species	Locality	Number of perianth segments (NPS)					Total
		4	5	6	7	8	
GEM	Wild						
	Zz		4	49	127		180
	Ng	1	59	499	69	2	630
	Sm		24	228	603		855
	Hb	8	43	89	40		180
	Total	9	130	865	839	2	1845
	(%)	(0.5)	(7.0)	(46.9)	(45.5)	(0.1)	(100.0)
	Cultivated						
	Zz			23	67		90
	Ng		1	48	86		135
	Sm			6	84		90
	Hb	1	1	28	105		135
	Total	1	2	105	342		450
	(%)	(0.2)	(0.4)	(23.3)	(76.0)		(100.0)
MUC	Wild						
	Hm		7	632	29	1	669
	Sd		1	331	8		340
	St		1	283	11		295
	Total		9	1246	48	1	1304
	(%)		(0.7)	(95.6)	(3.7)	(0.1)	(100.0)
	Cultivated						
	Hm		2	131	2		135
	Sd			89	1		90
	St			74			74
	Total		2	294	3		299
	(%)		(0.7)	(98.3)	(1.0)		(100.0)
TRI	Wild						
	Kk		1	29			30
	Sa		65	22			87
	Tk		128	187			315
	Td	1	53	170	1		225
	Mb		52	345	7		404
	It	3	132	262	7		404
	Total	4	431	1015	15		1465
	(%)	(0.3)	(29.4)	(69.3)	(1.0)		(100.0)
	Cultivated						
	Tk		6	39			45
	Td		27	123			150
	Mb		23	157			180
	It		19	159	2		180
	Total		75	478	2		555
	(%)		(13.5)	(86.1)	(0.4)		(100.0)

The alphabetical codes correspond to the locality codes in Table 1.

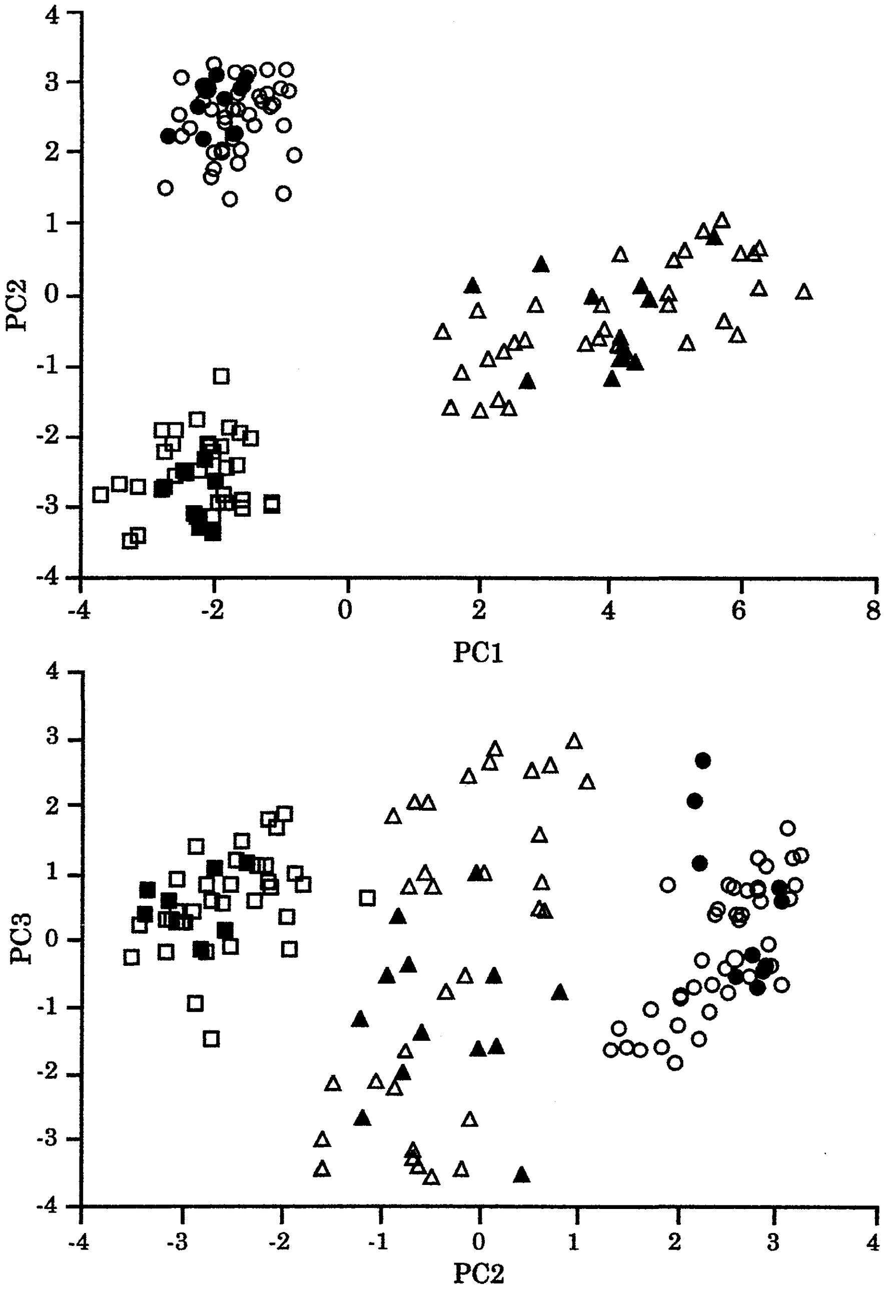

Fig. 5. Principal component analysis of *Schoenoplectus gemmifer* (circles), *S. mucronatus* var. *mucronatus* (squares) and *S. triangulatus* (triangles). Figures indicate two-dimensional plots of PC1 against PC2 (upper) and PC2 against PC3 (lower). The open and closed symbols indicate plants in the wild and cultivated condition, respectively.

ponent expressed a more biconvex nutlet and two stigmas and more perianth segments. The third principal component (PC3) accounted for 10.4 % of the total variation and was concerned with the width of the spikelet because the third component loading showed high loading on the character WSP. The plants with higher scores in the component tended to have wide spikelets.

The two-dimensional plots of PC1 against PC2 and PC2 against PC3 are shown in Fig. 5. In the two-dimensional plots of PC1 against PC2, the three species were clearly divided from each other. On PC1, *S. gemmifer* overlapped with *S. mucronatus*, although *S. triangulatus* was separated by a higher score from the other species. The three species were separated roughly from each other on PC2, although *S. mucronatus* and *S. triangulatus* overlapped slightly with each other in the wild condition. They were separated clearly into three groups in the cultivated condition. In the two-dimensional plots of PC2 against PC3, the three species were divided roughly from each other. On PC3, however, the three species overlapped heavily with each other and the scores of *S. triangulatus* varied widely.

Discussion

Schoenoplectus gemmifer was significantly different from *S. mucronatus* var. *mucronatus* and *S. triangulatus* in 15 characters, although the numerical ranges of 19 morphological characters, except for NST and NPS, overlapped among the three species. It might be considered that the four characters, such as LAN, LGL, AN/ON and PS/NU are available for the distinction of *S. gemmifer* from *S. mucronatus* and *S. triangulatus*. In addition to these, the surface appearance of the nutlets might also be useful.

The variation between *S. gemmifer* and the other species was discontinuity in the character NST. This is one of the most important characters in the distinction of *S. gemmifer* from the other species (Sato and Imae 1990, Sato et al. 2003). A similar case was reported for a relationship between *S. juncoides* and *S. hotarui* (Smith and Hayasaka 2002). The character NPS was variable among populations and growing conditions. The modes of two localities of *S. gemmifer* were six and the same as those of *S. mucronatus* in the natural condition. The modes were seven in the other localities in the wild condition and in all the cultivated conditions (Table 4). The number of perianth segments in plants of *Scirpus* L. s. l. is considered to be basically six (Koyama 1958). Species with more than seven perianth segments have rarely been reported in the genus *Schoenoplectus* (Koyama et al. 2000, Simpson and Koyama 1998, Strong 1994). Thus, the increase in the number of perianth segments might be a characteristic phenomenon in *S. gemmifer*. Nutlets with seven perianth segments were observed exceptionally in both *S. mucronatus* and *S. triangulatus*. In consequence, nutlets with seven or more perianth segments might be useful for the distinction of *S. gemmifer*.

In the principal component analysis, distinctive characters such as LAN, LGL, PS/NU, AN/ON, NST and NPS in *S. gemmifer* loaded heavily on the first two principal components: the former three characters being high loading on PC1 as a size factor and the others on PC2 as an nutlet factor (Table 5). In the two-dimensional plots of PC2 against PC1, the three groups of plants were divided from each other (Fig. 5). On PC1, *S. gemmifer* was separated from *S. triangulatus* but not from *S. mucronatus*, while *S. gemmifer* was separated clearly from *S. mucronatus* and roughly from *S. triangulatus* on PC2. Thus, *S. gemmifer* was different from *S. triangulatus* in the plant size and from both the species in the characters of the nutlets. It is therefore considered that the LAN, LGL and PS/NU loading heavily on PC1 are available for the distinc-

Table 5. Results of the principal component analysis. Component loadings of 21 characters on the first three principal components (PC1 to PC3) and cumulative variances of the first three principal components

Character	Component loading		
	PC1	PC2	PC3
LAN	0.949	0.020	–0.111
LSP	0.896	0.040	0.354
NSP	0.860	–0.055	–0.014
NGL	0.860	–0.037	0.391
LGL	0.812	0.430	–0.271
LPS	0.802	0.401	–0.218
PS/NU	0.799	0.389	–0.240
LPI	0.798	0.099	–0.480
WCU	0.758	0.401	0.128
NNU	0.743	–0.067	0.545
LIB	0.736	–0.185	–0.035
LCU	0.638	–0.349	0.064
AN/ON	–0.309	0.919	0.097
HON	–0.193	–0.891	–0.034
NST	0.433	–0.854	–0.008
HAN	–0.474	0.801	0.128
NPS	–0.344	0.664	0.276
WSP	0.184	0.430	0.738
WGL	0.139	–0.459	0.665
WNU	–0.490	–0.297	0.260
LNU	–0.102	0.036	0.035
Cumulative variance (%)	41.9	64.6	75.0

LAN: length of anther. LSP: length of spikelet. NSP: number of spikelets per culm. NGL: number of glumes per spikelet. LGL: length of glume. LPS: length of perianth segment. PS/NU: relative length of perianth segment to nutlet. LPI: length of pistil. WCU: width of culm. NNU: number of nutlets per spikelet. LIB: length of involucral bract. LCU: length of culm. AN/ON: rate of HAN to HON. HON: height of outside in biconvex nutlet. NST: number of stigmas. HAN: height of axis side in biconvex nutlet. NPS: number of perianth segments per nutlet. WSP: width of spikelet. WGL: width of glume. WNU: width of nutlet. LNU: length of nutlet.

tion of *S. gemmifer* from *S. triangulatus*. On the other hand, the three characters, AN/ON, NST and NPS, loading heavily on PC2 might contribute to the distinction of *S. gemmifer* from the other species.

Key to *Schoenoplectus gemmifer* and its related species

1. Gemma and linear leaf blade present; growing in rill or stream.......................... ....*S. gemmifer* (stream-form)
1. Gemma and linear leaf blade absent; growing in still water..............................2
  2. Biconvex nutlet; stigmas 2; perianth 6–7 segments....*S. gemmifer* (still water-form)
  2. Compressed trigonous nutlet; stigmas 3; perianth segments 6...............................3
    3. Anthers 0.9–1.7 mm long; glumes of spikelets 2.2–3.8 mm long; relative length of perianth segments to nutlets 0.75–1.40... ....*S. mucronatus* var. *mucronatus*
    3. Anthers 1.7–3.8 mm long; glume of spikelets 3.5–6.0 mm long; relative length of of perianth segments to nutlets 0.88–1.94........................*S. triangulatus*

In addition to the above-mentioned morphological characters, *S. gemmifer* has unique characters, such as linear leaf blade and gemma (Sato et al. 2003). In the genus *Schoenoplectus*, Koyama (1958) proposed the evolutionary trend that the leaf blade is degenerate and the leaf shape is a cylindrical sheath at the base of the culm. Thus, a linear leaf blade might be an ancient morphological character. The vegetative proliferation of *Schoenoplectus* plants was reported as an unusual phenomenon (Hayasaka and Ohashi 2000b, Hayasaka 2001). In *S. gemmifer*, however, this characteristic is easily confirmed in individuals growing in rills or streams. Thus, it might be considered that *S. gemmifer* is different phylogenetically from *S. mucronatus* and *S. triangulatus*.

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前田哲弥[a]，佐藤千芳[a]，内野明徳[b]：**ハタベカンガレイの変異とそれに近縁なヒメカンガレイおよびカンガレイとの形態比較**

ハタベカンガレイ *Schoenoplectus gemmifer* は，柱頭数，線形葉，無性芽の3つの特徴により，形態的に近縁なヒメカンガレイ *S. mucronatus var. mucronatus* および カンガレイ *S. triangulatus* から区別された新種である (Sato et al. 2003)．しかし，止水中に生育する個体では線形葉と無性芽は発達せず，上記の2種と混同されやすい．

本研究では，形態測定および主成分分析によって，3種間のより詳細な形態比較を行った．主成分分析の結果，植物体の大きさを表す第1主成分ではカンガレイが他の2種から分けられた．ハタベカンガレイは，主に痩果の形質を表す第2主成分（PC2）においてのみ他の2種から分けられた．PC2に対して主成分負荷量が高い形質は，痩果の横断面の形，柱頭数，および刺針状花被片数であった．したがって，これらの3形質は ハタベカンガレイの同定に有効な形質であることが分かった．

3種は次のように区別される．

1. 無性芽，線形葉を生じる ……………………………………………ハタベカンガレイ（流水形）
1. 無性芽，線形葉は生じない ……………………2
 2. 痩果は両凸型，柱頭は2本，花被片は6–7枚 …………………ハタベカンガレイ（止水形）
 2. 痩果は偏三稜形，柱頭は3本，花被片は6枚 ……………………………………………3
  3. 葯長0.9–1.7 mm，小穂の鱗片長2.2–3.8 mm，花被片の痩果に対する相対長0.75–1.40 ……………………………………ヒメカンガレイ
  3. 葯長1.7–3.8 mm，小穂の鱗片長3.5–6.0 mm，花被片の痩果に対する相対長 0.88–1.94 ……………………………………カンガレイ

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